Leveraging Embedded Training Systems to Build Higher Level Cognitive Skills in Warfighters

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ABSTRACT

Embedded Training Systems provide a new opportunity for training not only procedural or systems skills, but also the higher-level cognitive skills that are critical for successful performance on today's battlefield. We have developed a principled approach for training the essential cognitive skills underlying high levels of situation awareness (SA) and decision making that can be easily employed in future embedded training systems so as to significantly enhance this critical commodity. These training approaches include (1) SA Trainer which employs systematic experiential-based training to build essential knowledge bases and higher-order cognitive skills, (2) Virtual Environment Situation Awareness Review System (VESARS) which employs informed feedback on SA skills, team communications, and the accuracy and completeness of SA, and (3) the SA Virtual Instructor (SAVI) which builds critical SA skills by calibration of good and poor SA practices.

1.0   INTRODUCTION

New systems being built for C4ISR and other battlefield operations increasingly include embedded training capabilities – that is training that occurs on the actual systems and devices the soldier normally uses to perform his or her duties. While some of this training may take the form of more traditional Interactive Media Instruction (IMI), it also involves simulation based training in which actual operations can be simulated (with either live or virtual team mates and opponents) and the soldier being trained can interact with the controls and displays of the system in the same way he would in the real world. This train-as-you-fight concept has considerable advantages in terms of costs, time utilization and opportunities for better training outcomes.

Embedded training is likely to be used for training soldiers in system interaction, and in military doctrine and procedures. The real advantages of embedded training, however, go far beyond these standard training objectives. Embedded training systems also provide the perfect platform for providing the enhanced cognitive skills training that is critical in the future battlefield. In particular, we have been involved in ongoing work using these types of virtual simulations to train situation awareness (SA) skills and knowledge in military settings. SA is the key cognitive construct upon which decision making rests and one of the most challenging to develop and maintain in dynamic environments such as combat. These training approaches are based on research that shows the key challenges for SA and research on factors that distinguish experts from novices in these domains. They are also built on detailed cognitive task analyses in the military domain settings that reveal the critical SA elements for a given warfighter role and the challenges they must contend with.

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14. ABSTRACT

Embedded Training Systems provide a new opportunity for training not only procedural or systems skills, but also the higher-level cognitive skills that are critical for successful performance on todays battlefield. We have developed a principled approach for training the essential cognitive skills underlying high levels of situation awareness (SA) and decision making that can be easily employed in future embedded training systems so as to significantly enhance this critical commodity. These training approaches include (1) SA Trainer which employs systematic experiential-based training to build essential knowledge bases and higher-order cognitive skills, (2) Virtual Environment Situation Awareness Review System (VESARS) which employs informed feedback on SA skills, team communications, and the accuracy and completeness of SA, and (3) the SA Virtual Instructor (SAVI) which builds critical SA skills by calibration of good and poor SA practices.

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1.1 Cognitive Skills Underlying High Levels of Situation Awareness

In talking about situation awareness, we encompass all three levels of SA in our approach. Situation Awareness is "*the perception of the elements in the environment, within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future*" [3]. It therefore includes:

- Level 1 SA—Perception of the elements in the environment. The first step in building SA is to perceive the status, attributes, and dynamics of relevant elements in the environment. This will include important elements such as enemy, civilian, and friendly position and actions, terrain features, obstacles, and weather. Inherent in military operations is the difficulty associated with determining all the needed aspects of the situation due to obscured vision, noise, smoke, confusion, and the dynamics of a rapidly changing situation. Additionally, the enemy works hard to deny information on their troops and operations or to intentionally provide misleading information.

- Level 2 SA—Comprehension of the current situation. Comprehension of the situation is based on a synthesis of disjointed Level 1 elements. Level 2 SA goes beyond simply being aware of the elements that are present to include an understanding of the significance of those elements in light of the warfighter's goals. This level of SA is sometimes called situation understanding (SU). The warfighter assimilates Level 1 data to form a holistic picture of the environment, including a comprehension of the significance of objects and events. For example, an intelligence officer may need to assimilate the data from multiple sensors and reports to determine enemy intent or the impact of friendly operations on the degree to which an enemy unit can shoot, move, and communicate. Typically Level 1 SA (perceived data) must be interpreted (with reference to goals or plans) in order to have meaning as Level 2 SA. For example, a commander must understand the impact of discovering a new enemy unit on the conduct of a mission operation, so that he can rapidly make needed adjustments to ensure its success

- Level 3 SA—Projection of future status. The third and highest level of SA is the ability to project the future actions of elements in the environment, at least in the very near term. This is achieved through knowledge of the status and dynamics of the elements and a comprehension of the situation (both Level 1 and Level 2 SA). Commanders with a very high level of SA are able to project where and when the enemy will strike or what their next move might be. Warfighters with Level 3 SA are able to project how much time they have until reinforcements arrive or until a second volley of artillery fire arrives. This gives them the knowledge and time necessary to decide on the most favourable course of action to meet their objectives

1.1.1 Challenges for Novices

Expertise in a particular domain has a significant role in allowing people to develop and maintain SA in the face of high volumes of information transfer and system complexity [4]. This can best be explained in terms of two divergent ends of a continuous spectrum, as shown in Figure 1.
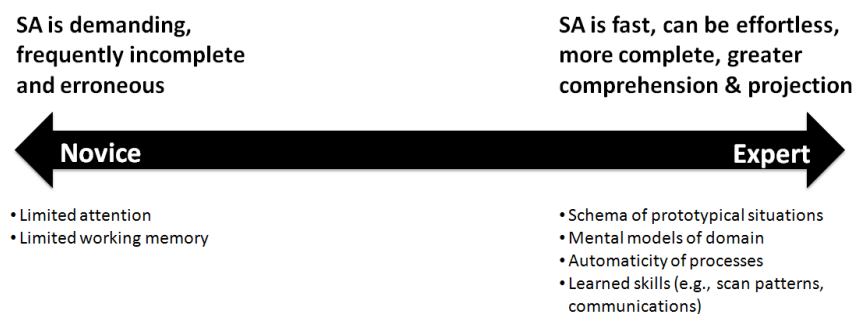
SA is demanding, frequently incomplete and erroneous

SA is fast, can be effortless, more complete, greater comprehension & projection

Novice ←———————————————————→ Expert

- Limited attention
- Limited working memory

- Schema of prototypical situations
- Mental models of domain
- Automaticity of processes
- Learned skills (e.g., scan patterns, communications)

Figure 1. Factors effecting SA in Novices and Experts in a Domain [1]

A person who is completely new to the systems and situations in a particular domain (e.g. a brand new first lieutenant or a soldier who is new to a combat zone) will be considerably overloaded in seeking to gather information, understand what it

means and formulate correct responses. They will be severely hampered in their efforts by both limited attention and limited working memory. Lacking other mechanisms, they will have to think through each piece of data and try to process it in working memory along with other pieces of data. Reading each report or listening to radio communications and interpreting that data will impose a significant burden. Properly understanding the significance of what is perceived will likely be problematic as well, as they will not have the experience base on which to interpret that information. So they will often remain far behind the demand curve in taking in and processing the information that forms the basis for good SA in this dynamic environment.

Their mental processes are further compromised by inefficiency. They lack the knowledge of when which information is really most important. Scan patterns tend to be sporadic and non-optimal. They may neglect certain key information or over-sample other information unnecessarily. This is not just a matter of needing to learn a set way of taking in information. Without knowledge of the underlying relationships between entities in the battlefield, they do not realize what information to seek out following receipt of other information. Thus the prototypical novice is quickly overloaded, inefficient, and error prone in developing SA. Decision-making and performance are highly compromised as a result. This is often the case reported today for new pilots or platoon leaders, for example, or for commanders facing a new kind of insurgent or weapon system. Luckily, development of expertise in a particular domain significantly reduces these problems through a number of mechanisms.

1.1.2 Mental Models

With increasing experience in a particular domain the model also details how people are able to develop a number of mechanisms that help to overcome these significant hurdles. The first of these is a mental model of the systems being operated and the operational domain. For example a pilot develops not only a mental model of how the aircraft operates, including its many subsystems and its aerodynamic performance in the physical environment, but also a mental model of flight operations including air traffic control (ATC) procedures and expected behaviour associated with interacting with ATC and with other pilots.

Mental models have been succinctly defined as "*mechanisms whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future states*" [5]. They are generally used to describe a person's representation of some physical system (e.g. how an engine or computer works), but also can concern other types of systems (e.g. how the enemy operates or how the military decision making process works). Mental models embody stored long-term knowledge about these systems that can be called upon to direct problem solving and interaction with the relevant system when needed. Mental models are highly useful in the process of developing SA [3, 4] and provide several advantages:

- Knowledge regarding which aspects of the environment are relevant and critical cues that have significance (e.g. a flattened area of grass or a hum of an engine). This knowledge is critical for directing attention in taking in and classifying information in the perception process, making that process much more efficient in the face of a large amount of information to potentially be processed.

- A means of integrating various elements to form an understanding of their meaning (level 2 SA). Understanding the significance of perceived system information is often very difficult without a mental model. Mental models provide the basis for interpreting perceived information (singularly or together) in terms of the individual's goals to form Level 2 SA.

- A mechanism for projecting future states of the environment based on its current state and an understanding of its dynamics (level 3 SA). Similarly, the projection of future system states is very difficult without a mental model. Accurately projecting what the enemy in a battle is likely to

do requires a very detailed mental model of not only the battlefield (terrain features, weather, obstacles), but also of the enemy (objectives, capabilities, doctrine, culture, tactics, techniques and procedures).

1.1.3 Schema of Prototypical Situations or Patterns

Over time, people will encounter many situations and from this will develop a type of library of prototypical situations, or schema, in memory.   Schema can be thought of as prototypical states of the mental model (i.e. a pattern consisting of the state of each of the relevant elements). By pattern matching between the current situation and schema, people can instantly recognize known classes of situations. *"Oh, this is just like what happened last month".* These prototypical situations can be learned through direct experience or vicariously through formal training or the case studies and storytelling that are endemic in many professions. *"This is just liked what happened to the aircrew in the Azores accident".* A critical feature of schema is that new situations need not be exactly like previously encountered situations to achieve a match. Rather only a few critical cues may be required to lead to a match or a near match.

Pattern-matching to learned schema provides a considerable short cut for SA and decision-making. Rather than processing data to determine level 2 or 3 SA (requiring working memory or exercising the mental model), that information is already a part of the schema and must merely be recalled. Klein has called this recognition primed decision making [6]. The critical factors for achieving good SA through this mechanism are recognizing the critical cues that are used for pattern matching, and having a good stock of such schema in memory. In addition, it appears that some people are better at pattern matching than others, and this attribute has been shown to be correlated with SA [7].

Very often scripts, set sequences of actions, have also been developed for these schema, so that much of the load on working memory for generating alternate behaviours and selecting among them is also diminished.   These mechanisms allow the commander to simply execute a predetermined action (e.g. follow doctrine or rules of engagement) for a given recognized class of situations (based on their SA). The current situation does not even need to be exactly like one encountered before due to the use of categorization mapping — as long as a close-enough mapping can be made into relevant categories, a situation can be recognized, comprehended in terms of the model, predictions made and appropriate actions selected. In that people have very good

Figure 2. Schema and Mental Models Significantly Facilitate the Development of SA [2]

pattern matching abilities, this process can be almost instantaneous and produce a much lower load on working memory making high levels of SA possible, even in very demanding situations.
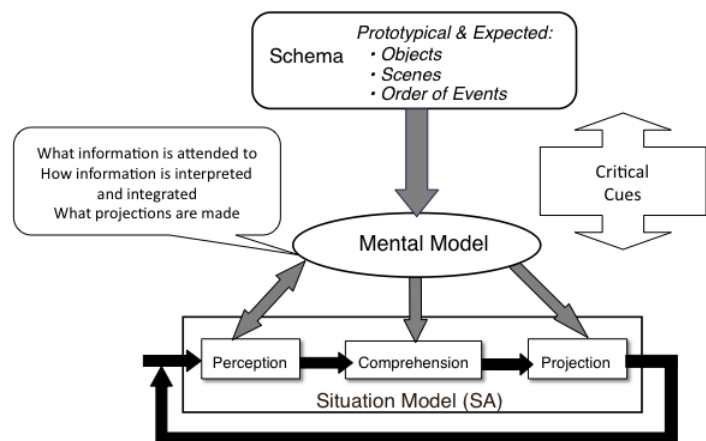
1.1.4 Critical Skills

In addition to the key knowledge constructs of mental models and schema, experts also tend to develop superior skills for acquiring and processing information in their environment that must be learned or trained. Pilots learn to communicate with ATC and to scan their instruments to make sure their knowledge of the situation does not get out of date. Air traffic controllers learn how to scan their radar maps efficiently based on traffic patterns in the sector.   Military officers learn how to gather and disseminate

key information on the radio, how to listen for information that is relevant to them while ignoring other information, and where to post troops as listening and observation posts to insure that key information is gathered and passed on in the first place. Much of the gathering of SA is not just passive, waiting for key information to be presented, but is an active process. The information that is available to military pilots, for example, is dependent on how they setup and operate their radar (search patterns, where it is focused, modes), what frequency they tune their radios to, and when they request information from others. Thus their actions determine what information they will obtain. All of these are examples of learned skills, specific to each domain, that improve with expertise and that contribute to higher SA among experts.

1.1.5 Study of SA Training Needs in Infantry Operations

As an example in the military domain, Strater, Jones and Endsley [8] surveyed 43 individuals who train new platoon leaders on problems observed with SA in these new officers. Issues that were rated as a frequent problem by more than 25% of the respondents are shown in Table 1. Problems in communication posed a major problem for new platoon leaders leading to poor SA. These problems ranged from not requesting information to not communicating key information. In addition there were significant problems reported in gathering information on the combat readiness status of the opposing force and one's own troops.

Comprehension problems were also noted, including failing to assemble bits of information together into a coherent picture and not specifying alternate courses of action (COAs), along with not understanding task priorities, the impact of load and travel on fatigue, and soldier positioning to minimize fratricide. Instructors rated understanding enemy strengths and weaknesses, likely areas of strategic significance to the enemy, and enemy expectations of friendly actions as major problem areas for SA in new platoon leaders.

With regard to Level 3 SA, a lack of contingency planning was identified as a problem area, as was failure to project the usage rate of ammunition and supplies. Problems with SA regarding the opposing force were also found at the projection level, as trainers noted that new platoon leaders have difficulty projecting a likely enemy COA, as well as their disposition around heavy weapons.

Poor skills for gathering information are particularly problematic in military settings, as very little information presents itself otherwise. It was found that the officers often were not communicating key information because they assumed they knew what was going on, or that the information did not need to be passed on. In addition, it appears that novice platoon leaders suffer greatly from not having good mental models or schema. They are quickly overwhelmed by information, are slow to grasp which information is important and where to look for important follow-up information. Without these schema, they also faired poorly in integrating information to understand its significance and to carry out projection and contingency planning. These findings are well in line with the types of SA problems experienced by those in other domains [1], and are indicative of the areas that future SA training programs should address.

Table 1. SA problems for new platoon leaders (% reporting) [8]

Level 1 SA: Failure to Correctly Gather/Detect the Critical Information in the Situation	
Not detecting information due to attentional narrowing	27 %
Not utilizing a standard reporting procedure	30 %
Not carrying out standard operating procedure	28 %
Poor intelligence information due to:	
Not requesting pertinent intelligence	31 %
Not employing squads tactically to gather needed information	30 %
Not determining reliability/timeliness of intelligence information	26 %
Poor communication caused by:	
Not requesting information from squad leaders	30 %

Not requesting information from commander	30 %
Not communicating key information to commander	35 %
Not communicating key information to squad leaders	30 %
Not communicating key information to other platoons	44 %
Not monitoring company net	28 %
Not communicating overall situation/Commander's Intent to squads	28 %
Not determining own combat readiness status	
Experience and training	26 %
Timing/location of direct/indirect fire support	30 %
Not determining combat readiness status of opposing forces	
Number and severity of casualties	37 %
Physical fatigue	30 %
Mental fatigue	31 %
Movement and current position of troops	28 %
Weapons types, characteristics and quantities available	33 %
Location of direct/indirect fire support	44 %
Ammo and supplies availability	33 %
Availability of reinforcements	37 %
Heavy weapons location	40 %
Past behaviour and tactics	26 %
Impact of current and future weather factors	26 %
Level 2 SA: Failure to Comprehend the Situation (although basic information is detected)	
Not assembling bits of information together to form a coherent picture	29 %
Not specifying alternate/supplemental plans/courses of action	32 %
Not developing an understanding of:	
Task priorities	33 %
Impact of soldier load and distance travelled on troop fatigue	33 %
Positioning soldiers to minimize the risk of fratricide	25 %
Enemy strengths and weaknesses	29 %
Likely areas of strategic significance to enemy	27 %
Enemy expectations of friendly actions	34 %
Level 3 SA: Failure to Project the Future Situation (though current situation is understood)	
Lack of contingency planning	39 %
Failure to project the following:	
Usage rate of ammunition and supplies	36 %
Likely enemy COA from available information	33 %
Location of enemy troops around heavy weapons	32 %
Failure to Effectively Perform the Necessary Mission Tasks	
Poor mission planning	27 %
Poor responses to unexpected/unplanned events	36 %
Poor time management	45 %
Poor task prioritization	28%

2.0 TRAINING APPROACHES FOR IMPROVING SITUATION AWARENESS

We have been building a set of training approaches for improving the cognitive skills and building the cognitive structures underlying high levels of SA. These training approaches selectively target those skills and structures that are specifically needed in a given domain, based on both the cognitive model described above, as well as detailed analyses of the SA requirements and challenges that exist in each domain. These approaches are not a "one size fits all" solution, but rather an integrated set of tools that can be customized for the domain, the needs of the trainees in that domain, and the objectives and operational realities of the organization.

2.1 SA Trainer

The SA Trainer employs rapid experiential learning in support of mental model & schema development. In normal operations, over the course of many months and years, individuals will gradually build up the experience base to develop good mental models and schema for pattern matching upon which SA most often relies. With the SA Trainer, we work to boot strap this natural process, by exposing the trainee to many, many situations in a very short period of time using IMI and embedded training techniques. This experiential learning is very structured, so as to help the trainee get the most out of the information they are exposed to.
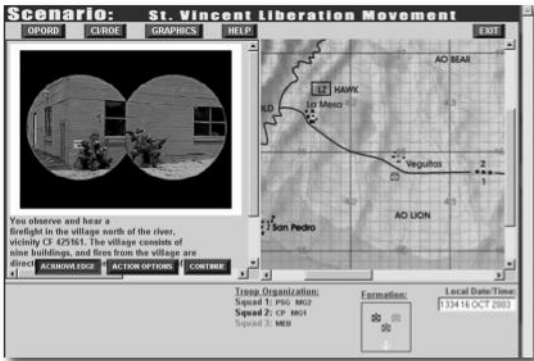

Figure 3. SA Trainer for Infantry Operations

The SA Trainer employs realistic mission scenarios with opportunities for complex operational decisions. The target is to provide an increased opportunity for exposure to a variety of situations which supports the development of situation-based knowledge stores, to train recognition of critical cues that signal prototypical situations, to support trainee information integration and decision making, and to promote understanding of the importance of consequences, timing, risk and capabilities associated with different events, behaviours, and decision options. In schema training, trainees learn what it means to develop SA in the environment, learn to build higher level SA out of data, and receive training toward projecting future events in prototypical situations.

SA Trainer introduces SA using the "what", "so what", and "now what" description model, which maps to the three levels of SA in a format that is easy to recall. In this manner, trainees learn to think about their SA needs in terms of **WHAT** *information do I have or do I still need,* **SO WHAT** *does this information mean in terms of my goals, and* **NOW WHAT** *will happen next, or what should I be prepared to do to deal with the future situation?* Virtual training instructors (avatars) lead trainees through various situations to help focus on critical metacognitive skills related to identifying critical cues, evaluating the relevance of information, both available and missing, and developing contingency plans for likely near future events. SA Trainer helps trainees learn *how* to think about situations, rather than just *what* to think, so that they quickly recognize prototypical situations, adapt to novel situations, and make high quality decisions during real operations. As trainees make decisions, the avatar may prompt trainees to consider what they know, what they need to know, how they can best gather missing information, and how to evaluate conflicting information.
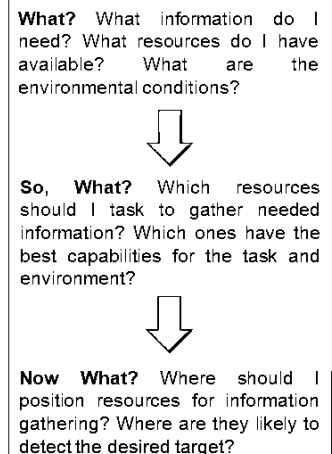
The training specifically focuses on creating Levels 2 and 3 SA from the basic information available in the environment. It also focuses on training soldiers in the critical cues that signify prototypical classes of situations, for instance leading indicators for IEDs. This type of training helps build the mental models and schema necessary to put cues together to form the needed comprehension and projection. As such, it is experientially based (i.e. involves mission scenarios and examples) and allows trainees to build an understanding of cues and events in a multi-modal manner. A key advantage of this type of training is that it provides a concentrated learning environment for building up the key foundations for SA that would take years to accumulate in the field and would be very hazardous. In an investigation of the efficacy of SA Trainer, Strater, et. al [9]found that military cadets who had received training with the infantry version
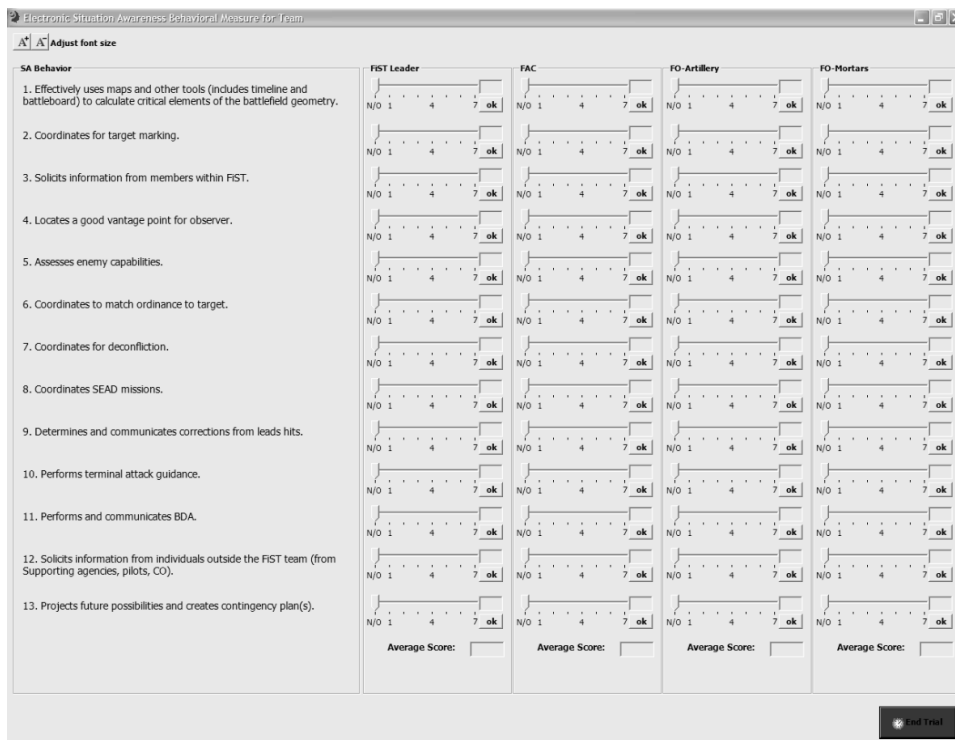
of SA Trainer performed better in a field exercise, and were more likely to have confidence in their SA. In addition, we have recently completed a version of SA Trainer specifically directed at training soldiers to detect and defeat IEDs for the USMC.

2.2 Virtual Environment Situation Awareness Review System (VESARS)

Feedback is critical to the learning process. In order to improve SA, soldiers need to receive feedback on the quality of their SA. For example, inexperienced soldiers may fail to appreciate the severity of threatening conditions because they have come through similar conditions in the past just by luck. Unfortunately, this also reinforces poor assessments. It is difficult for individuals to develop a good gauge of their own SA in normal operations. Training through SA feedback allows trainees to fine tune critical behaviours and mental models based on a review of their SA performance [10]. The VESARS method involves the use of SA measures that assess trainee SA in three areas: (1) a behavioural rating tool that assesses warfighter and team actions, (2) a communications rating tool that evaluates team communications, and (3) a SA query tool that allows direct assessment of warfighter and team SA [11, 12]. VESARS was specifically designed to work well with virtual and embedded training environments, or it can also be employed in field exercises.

2.2.1 SA Behavioural Rating

VESARS presents aspects of SA behaviour important to acquiring and maintaining SA for a particular job function or role. Instructors can rate individuals or teams, based on the appropriate behaviours for building SA relevant to each job. This particularly supports the less experienced evaluator, pointing out what to look for in relation to physical actions for situation assessment. Each behaviour can be rated on a Likert scale including ratings from 1 to 7, or "not observed". A particular utility of the VESARS behavioural rating system lies in being able to assess how the quality of the situation assessment behaviours of the trainees changes over time, as the ratings can be made throughout the training session and are recorded along the timeline. This avoids the post-trial memory recall problem associated with making an after-action assessment of all behaviours and the overgeneralization that is common to such ratings. The VESARS behavioural ratings for each team member and each item on the rating tools are also averaged to provide a behavioural score for the role and for a particular situation assessment skill. The results are recorded at the end of a training trial into a data file for later review.

Figure 4. VESARS SA Behavioural Rating Form Example (USMC Fire Support Team)

2.2.2 SA Communications Rating

Team communications is critical to the formation of SA in many team environments, particularly those in most military operations. Various team communications have been categorized as relevant to SA on the rating tool. Each item on the rating scale has been identified as an important team communication for acquisition and dissemination of goal-related information. In using this tool, the instructor listens to the natural communications of the team members and rates the quality of their verbalizations as either good or bad (poor) statements. The system tracks the counts of good and poor statement over the course of a scenario. At the end of a training trial, the rater has the opportunity to review summary data for SA communications ratings in order to provide an overall team communications rating. The rating scale includes descriptive phrases that serve as guidelines to raters when providing a score from 1 to 5. The descriptions help rates assess overall communications quality for consistent ratings of team communications.

Figure 5. VESARS SA communications rating scale example (USMC fire support team)

2.2.3 SA Probes

Direct objective assessment of an individual's SA through relevant queries measures an individual's SA (their perception of what is happening in a simulation or exercise) and provides feedback on how that compares to what was actually happening at the time. This type of information can be highly useful in teaching an individual the ways in which their processes may be deficient and how to correct them. VESARS accomplishes this goal through a modification of the Situation Awareness Global Assessment Technique (SAGAT) [3, 13]. SAGAT has been adapted for SA training by the addition of feedback to individuals on the accuracy of their responses. For instance: "You thought you were here when actually you are there. You had hostile individuals following, but were unaware of it. You missed noticing that the earth had been disturbed along that route, which is a key indicator for IED activity".

The VESARS SA Probe tool supports the person administering SA probes in identifying relevant probes over the course of the training scenario, selecting and presenting probes in real time, and recording responses to probes. The comprehensive list of SA probes is developed for the domain (based on a detailed Goal Directed Task Analysis (GDTA) conducted for each role) and is housed in a database that is accessed by VESARS. The system scores each probe as correct or incorrect, retaining both the trainee response and the correct, ground truth response recorded by the administrator. The results are then stored in a data file that can be accessed for review using the review tool to be explained later.

To incorporate shared SA, the GDTA data of all team members are cross-analyzed to highlight the shared goals and shared SA needs. In many cases there are similar informational elements that are needed for different purposes across team members. SA probes can be developed to determine if training team members have the same understanding of shared SA elements. The SA probe database identifies probes that are potential shared SA queries, and indicates to which team members each SA probe is associated. As some information requirements are relevant to all members of the team, SA probes designed to assess knowledge of these information items can be posed to any member of the team. Some information requirements are only applicable to a limited set of team members. Such SA probes would be identified in VESARS as only relevant to those few positions.
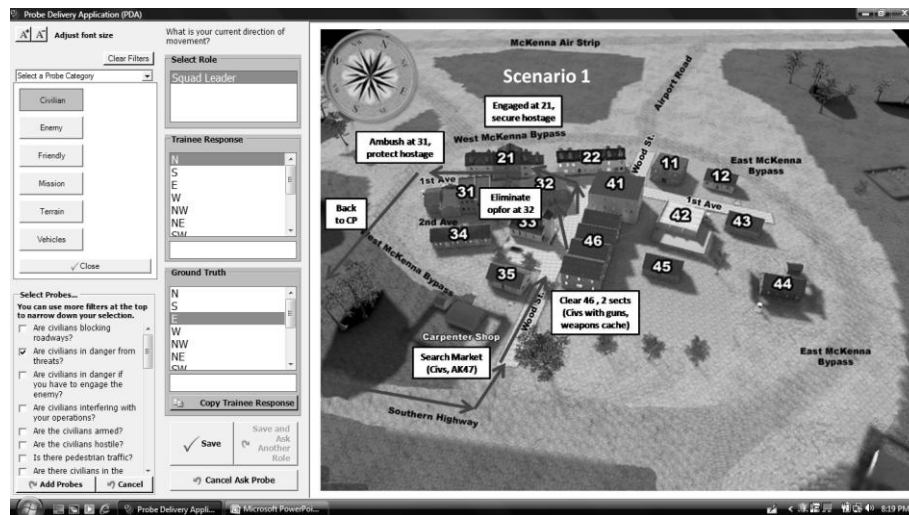
Figure 6. SA Probe delivery tool example (USMC fire support team)

2.2.4 Use of VESARs in After Action Reviews (AAR)

SA training through feedback involves providing knowledge of results immediately following training so that trainees understand the degree to which they were able to acquire SA and use it to meet operational goals. This kind of feedback enhances the utility of AAR sessions as it provides quantitative and qualitative results that the training coordinator can map directly back to scenario events. This approach requires valid and reliable measures of SA that are based on theory and empirical results. SA measures for training and instructions should meet specific criteria to ensure they provide "good" results for "feeding back" for training. Research-based criteria (e.g., [14, 15, 16])suggest that measurement should: map to key performance outcomes and goals for the domain, address both team and individual deficiencies, facilitate insight into team interactions, meet construct and content validity, be reliable, defensible, and relevant, be multifaceted, and be practical for use and implementation. The SA and human performance measures developed for our SA-oriented training through feedback approach are designed to meet all of these criteria and to provide detailed and specific SA review. The AARs can be conducted either in a classroom setting following the exercise, or virtually through built-in AAR tools embedded within the equipment.

Data on the accuracy of each team member's SA, their associated SA behaviours and SA communications over the course of the mission can be presented as discussed, as well as how these factors affected the overall SA and performance of the team. This creates a detailed template for conducting the AAR and for providing actionable feedback to the trainees to enhance the learning experience for these critical cognitive skills.

SA Overview

Overview | SA Probes | SA Behaviors | SA Communications

Print...

- SA is the perception of the elements in the environment, the comprehension of their meaning in terms of task goals, and the projection of their status in the near future.
- This table shows a summary of trainee accuracy on SA probes. The first row shows the scores of the entire FiST on SA probes. The subsequent rows show the accuracy of each role within the FiST.
- Beside each role are scores on total SA, level 1 SA, level 2 SA, and level 3 SA. Level 1 SA refers to the perception of the elements in the environment, level 2 SA refers to the comprehension of the current situation, and level 3 SA refers to the projection of future status.

	Overall SA	Level 1 SA (Perception)	Level 2 SA (Comprehension)	Level 3 SA (Projection)
FiST	78%	86%	77%	62%
FiST Leader	81%	79%	83%	82%
FAC	82%	95%	83%	50%
FO-Artillery	66%	76%	64%	55%
FO-Mortars	76%	84%	74%	63%

- Shared SA is the degree to which team members have a consistent picture of what is happening. Shared SA is evaluated by comparing the responses of the team members on SA probes that are common to two or more members.
- This table shows the accuracy of the FiST trainees on SA probes that they should have common knowledge on.

	Shared Probe Count
All teammates correct	7
1 teammate wrong	2
2 teammates wrong	0
3 teammates wrong	N/A
4 teammates wrong	N/A

Shared SA Probes List

Print...

| Probe	Category	Friction Point	Phase	SA Level	FiST Leader Response	FAC Response	FO-Mortars Response	FO-Artillery Response	Ground Truth
What are the weather effects on the marking mission?	Marks		Planning Phase, Execution Phase	Level 2	Not Queried	Not Applicable	dust reduces visibility	dust reduces illumination	dust reduces visibility
Does the aircraft cross the gun target lines?	CAS	CAS aircraft cross GTL	Planning Phase, Execution Phase	Level 1	Not Queried	Not Queried	No	Yes	Yes
What are terrain effects of marking mission?	Marks		Planning Phase	Level 2	terrain block line of sight	Not Applicable	provide cover and/or concealment	Not Queried	terrain block line of sight
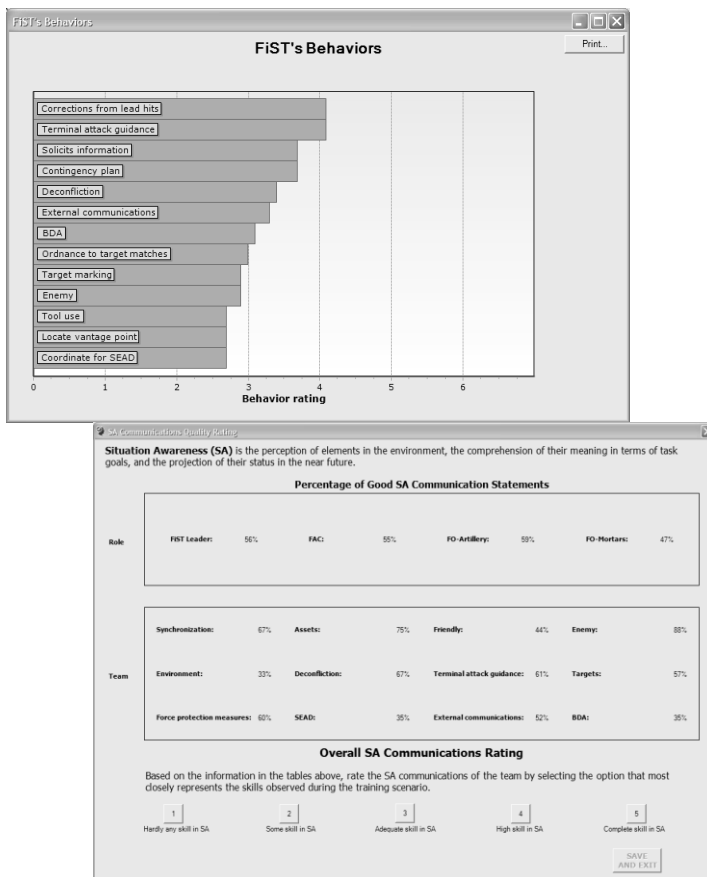
Figure 7. Examples of VESARS Feedback for use in the After-action Review

VESARS was initially developed for the U.S. Army Research Institute for training small units in urban combat settings, and has been expanded to fire support teams for the US Marine Corps, to homeland defence applications, and to mission control training for NASA.

2.3 Situation Awareness Virtual Instructor (SAVI)

Training others is a powerful opportunity for the trainer to learn as well as for the student. Research has shown that acting in the role of instructor also serves to facilitate learning [17, 18]. Most new trainers experience an exponential learning curve during the initial transition from doing a task to training others on a task. The Situation Awareness Virtual Instructor (SAVI) trains warfighters on the behaviours that are consistent with and important to good SA by allowing trainees to play the role of the trainer to rate the actions (behaviours and communications) of an individual or team and provide a rationale for their rating. SAVI integrates behavioural and communications training through embedded training technologies so that warfighters can observe performance and understand how information gathering and dissemination components (e.g., attention and perception, information discovery and filtering, information prioritization and integration, use of operational tools, information exchange and provision contextual content, team coordination, etc.) interact to impact global SA. The objective behind this training method is that the process of critically evaluating the behaviours and communications portrayed in the videos allows trainees to gain a deeper understanding of how these behaviours and communications support the acquisition of superior SA.

The SAVI approach leverages the exponential learning that occurs during either peer instruction or the transition from trainee to trainer. Trainees quickly learn what behaviours are appropriate for various operational situations, because they observe these aspects of performance and provide their assessments on the quality of the performance. Trainees are able to refine their mental models of good SA behaviours and communications as they also compare their assessments to those provided by domain experts. Behavioural training facilitates understanding of how active situation assessment promotes SA for maintaining the tactical advantage.

Figure 8. Examples of SAVI for Mission Control

3.0 CONCLUSION

Taking advantage of the capabilities of embedded training tools involves far more than translating the same old training techniques to a new platform. The real advantage will be seen when we move from simply training the rote skills, towards training the cognitive skills that allow warfighters to utilize their equipment and techniques *in situ* to achieve the best performance for the situation at hand. As much more sophisticated command and control tools are developed, the cognitive aspects of warfighting will become even more critical than they have been in the past. In this paper we advance several techniques and tools that have been developed for building the cognitive skills that will be needed on tomorrow's battlefields. These tools can be incorporated into embedded training programs to allow warfighters to develop and hone the needed SA skills for achieving high levels of performance.

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